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Opportunities and challenges for seasonal climate forecasts to more effectively assist smallholder farming decisions

The ability of smallholder farmers to utilise seasonal climate forecast (SCF) information in farm planning to reflect anticipated climate is a precursor to improved farm management. However, the integration of SCF by smallholder farmers into farm planning has been poor, partly because of the lack of forecast skill, lack of communication and inability to see the relevance of the SCFs for specific farming decisions. The relevance of seasonal climate forecasting in farming decisions can be enhanced through improved understanding of SCF from the smallholder farmers' perspective. Studies that have been done of how smallholder farmers understand SCF and how the available SCFs influence smallholder farmers' decisions are limited. Therefore, the objective of this paper was to review how smallholder farmers make decisions on farming practices based on SCFs and the challenges and opportunities thereof. The review shows that the majority of smallholder farmers in Africa make use of either scientific or indigenous knowledge climate forecasts and, in some cases, a combination of both. There are mixed results in the area of evaluating benefits of SCFs in decision-making and farm production. In some cases, the outcomes are positive, whereas in others they are difficult to quantify. Thus, the integration of SCFs into smallholder farmers' decision-making is still a challenge. We recommend that significant work must be done to improve climate forecasts in terms of format, and spatial and temporal context in order for them to be more useful in influencing decision-making by smallholder farmers.

Significance:

- At the farm level, making the right decisions at the right time is rendered even more difficult in light of the increasing frequency of extreme weather patterns.
- The threat of climate change makes accurate seasonal climate forecasting essential for African smallholder farmers.
- Technological, social and interdisciplinary issues, communication and scale are some key challenges which impact the utility and uptake of SCFs in rural smallholder farms.
- The integration of both scientific and indigenous knowledge forecasts is an opportunity for further exploration.

Introduction

Smallholder farmers, defined as farmers who possess small pieces of land largely below 2 ha¹, constitute nearly 60% of the farming population in sub-Saharan Africa and are vital to food security in this region². Simplicity, use of 'old-fashioned' technology, low income, high seasonal labour fluctuations, and women playing a key role in production are some of the main characteristics of the smallholder farming systems.¹ The smallholder farmers grow subsistence crops and one or two cash crops and rely almost solely on household labour. Besides a general lack of resources – such as seeds, insecticides, fertilisers, hay, water – smallholder farmers' high dependence on rainfed farming makes them more susceptible to effects of climate variability and change.³ Consequently, there is a need to minimise the effects of climate variability and change on smallholders' agricultural production. One way to contribute to improving production is by increasing the use of seasonal climate forecasts (SCFs).

The timely availability of SCFs to smallholder farmers can improve their decisions in efforts to increase and sustain agricultural production.⁴ Rainfall amount and distribution, the extent and the commencement date of the rainfall season, as well as the frequency of dry spells, are some of the important climatic factors that influence farming decisions. However, these key climate variables vary substantially from year to year due to climate change.² In consequence, an accurate SCF is deemed crucial to benefit smallholder farming in Africa.

Sowing date, which cultivar to plant, the type and amount of fertiliser application, and livestock-related management options are decisions associated with climatic conditions.⁵ Several studies indicate that SCFs may have the capacity to increase the resilience of African agriculture to weather shocks and reduce vulnerability to climate extremes such as droughts and floods.^{6,7} What remains unclear is how farmers would use SCF information on crop and livestock management decisions and whether doing so would benefit them.⁸ The adoption of SCFs in management practices and farming decision-making strategies has been inadequately exercised by subsistence smallholder farmers for various reasons.⁵ Some of the reasons cited for low uptake of SCFs in farm decision-making are the complexity and probabilistic nature of the SCF information provided and in some instances incompatibility with existing practices.⁹ Thus, it is important that SCFs be presented in formats that suit smallholder farmers' needs. The questions we considered are: how do rural farmers appreciate the value of SCFs; and how do they use SCF information for their benefit? Some studies have provided insight into spatial, temporal and format issues, including challenges in the SCF application to agriculture, but there has not been a comprehensive review of applied social science research that synthesises farmers' perceptions of SCFs as well as the use of SCFs to adapt to climate variability risks.¹⁰

Therefore, the objective of this review was to determine how smallholder farmers make on-farm decisions based on SCFs and the challenges and opportunities thereof.

Seasonal climate forecasts available to smallholder farmers

Smallholder farmers have access to both scientific and indigenous knowledge SCFs.¹¹ Scientific seasonal climate forecasts (SSCFs) are delivered through a number of sources, for example, regional climate outlook forums (RCOF), national meteorological offices, and research institutes. SSCFs are disseminated through media like radio, television, newspapers, bulletins, websites, and farmers' workshops. The dissemination approach often involves collaboration with government agricultural officials to assist in the interpretation of SCFs to farmers for the majority of Southern African Development Community countries and agribusiness; for example, in countries such as Burkina Faso and Senegal.¹² In contrast, indigenous knowledge climate forecasts are produced locally by rural communities through environmental observation and traditional experiences.¹³ These are disseminated via oral and social communication horizontally in the immediate community and vertically through generations. Although there is some convergence between SCFs and indigenous knowledge system (IKS) forecasts, the following sections provide some distinction between the two sources of SCFs.

Scientific seasonal climate forecast products

RCOF and national meteorological services are the main providers of SSCF information for agriculture. National meteorological services provide mainly weather forecasts (temperature, rainfall, frost, etc.) on a daily basis, but they also work with RCOFs for SCFs. RCOFs produce and deliver seasonal forecasts to stakeholders in climate-sensitive sectors in Southern (SARCOF), Eastern (GHACOF), Western (PRESAO) and Central Africa (PRESAC) (Table 1).

Table 1: Regional climate outlook forums (RCOFs) in sub-Saharan Africa

Forum	Main seasonal climate products	Issuing period	Forecasted seasons
Southern Africa RCOF (SARCOF) (Southern Africa)	Rainfall, temperature, frost, food security status	Aug/Sep	Oct–Mar
Greater Horn of Africa COF (GHACOF) (Eastern Africa)	Rainfall, temperature, frost, food security status	Aug, Feb	Oct–Dec, Mar–May
Prévision Saisonnière en Afrique de l'Ouest (PRESAO) (West Africa)	Rainfall, temperature, frost, food security status	May	Jul–Sep
Prévision Saisonnière en Afrique Centrale (PRESAC) (Central Africa)	Rainfall, temperature, frost, food security status	Sep/Oct	Oct–Dec

Adapted from Hansen and Mason¹²

The scientific forecast products are predominantly rainfall and temperature estimates. Additional products may include frost and other extreme weather events such as cyclone occurrence. Scientific forecast alludes to prepared information and products about the atmosphere–ocean processes over short (hours to days) and long (seasonal to decadal) scales.¹³ However, scientific forecasts are not normally packaged to match the requirements of rural farmers in terms of the content, scale accuracy and reliability. According to Vermeulen et al.¹⁴, these variables have constrained the extensive use of SCF among rural smallholder farmers. For most African countries, the current SCFs show a bias towards the prediction of normal conditions because of limited forecasting skill. A rainfall forecast expressed as below normal to a smallholder farmer may be inadequate for the farmer to make a clear decision on farm management. This is because the meaning of the rainfall prediction of below normal must be interpreted in terms of the expected volume and distribution of the rainfall. For example, the volume of expected rainfall helps farmers choose the crop variety.

The distribution of rainfall is important in determining the timing of field operations such as when to plant, when to fertilise and when to weed. The insufficient number of adequately equipped data recording weather stations is cited as the main challenge with scientific climate information in Africa¹⁵, especially in rural communities. This challenge influences the analysis of the past climate and the capacity to create SCFs that suit local level contexts. As a result, the reliability and accuracy of the SCFs are compromised. The methods of communication used to access these data or information are also not available to all rural farmers.

The potential for SCFs of rainfall for parts of Africa is still high. However, the capacity to forecast seasonal rainfall remains variable within diverse areas of the continent.^{16,17} Moreover, SCF data are for the most part supply driven, at the national level, and reflective of farmers' needs.¹⁷ In effect, smallholder farmers eventually revert to IKS for what they deem to be more accurate forecasts.

Indigenous knowledge seasonal climate forecast products

IKSCF plays an important role in climate forecasting in Africa's smallholder farming communities, particularly in occasionally predicting local weather information and frost. The term 'indigenous knowledge' is entrenched within the literature; however, other terms such as local, ethnographic, traditional or folk knowledge, are also used.¹⁸ In this review, the term 'indigenous knowledge' was adopted to refer to the sum of facts and place-based knowledge known or learnt from cumulative day-to-day experience, or acquired through observation and study, and handed down from generation to generation by individuals and communities.^{19,20}

There are concerns over incorrect IKSCF application and changes in baselines utilised because of changing climate conditions, increasing population and other natural pressures.^{11,21} IKSCF is suggested by some studies as an appropriate entry point for climate change and adaptation research.^{22,23} To ensure effective change in practices by smallholder farmers, climate information from different source needs to be translated into attestable formats to enable creation of a SCF that is beneficial for farm decision-making at given temporal and spatial scales.¹⁵ The translation should involve the climate-affected smallholder farmers and other key stakeholders, including meteorological services.

Comparison between SSCF and IKSCF products

The SSCFs differ from IKSCF in scale and, to some extent, in the indicators used. Some of the principles of prediction of the indicators like wind flow and temperature changes of IKSCFs converge with those of SSCFs. The SSCFs are developed using indicators such as wind and sea surface temperature, which are primarily meteorological, whereas IKS seasonal climate is highly specific to the local area. IKSCFs are derived from an intimate interaction with micro-environment observations made over a period of time. SSCFs are generated at a much larger geographical scale. The reliability of the IKSCF indicators is not guaranteed, but they help the farmer to prepare for the timing and distribution of rainfall, whereas SSCFs help farmers prepare for the volume of rainfall.²⁴

Value of SCFs on farm management decisions

Although there has been continuous improvement in the technology of climate forecasting to manage climate risks, it has been problematic to measure the value of SCFs in many uses, especially in smallholder agriculture. The value of SCFs can be defined as the net benefit a smallholder farmer incurs from their use,²⁵ which depends on the farmer's readiness to diverge from past decisions, the characteristic anticipated climate conditions, and the possible distribution of SCFs with other communities.¹⁷ In some developing countries, studies indicate an increase in farmers' income resulting from the provision and utilisation of SCFs.^{21,26}

So why is the method of evaluating the socio-economic value of SCF so problematic? A number of researchers agree that a prerequisite for the value of SCF is that their use should result in changes in farm management decisions,^{27,28} subsequently bringing about outcomes that differ from those based on maintaining the status quo. Based on the SCF deviation from long-term average approach, Garbrecht and Schneider²⁹ designed a technique to assess the usefulness of SCFs. According to Garbrecht and Schneider²⁹, the usefulness of SCFs is a component of the deviation of the

SCF from the long-term average and this helps smallholder farmers adjust their farm management decisions in line with the deviations. Hence it is important to look at the opportunities and challenges in SCFs.

Opportunities and challenges for effective (scientific) SCFs

In addition to SCFs, other factors such as input costs, target markets and production level also play an important role in agricultural decision-making.²⁶ The largest opportunity for SCF is thus to take an holistic approach in the provision of climate forecasts to smallholder farmers that would take into account context, socio-economic status of the farmer, and technical aspects of the forecasts, e.g. skill and format. Interdisciplinary studies have been suggested as a way of exploring farm decision-making and integration of social and climate science in order to enhance the value of SCFs.³⁰ Success in the use of SCFs in decision-making has occurred when forecasts are delivered in participatory modes.³¹ There are, however, many challenges.

Technical constraints include the spatial and temporal resolutions of forecasts. Traoré et al.³² argue that 'high spatial resolution is required to allow management decisions on a field-scale'. Smallholder farmers' spatial scale refers to village or ward level. Farmers' decisions on cropping-cycle activities and operational options require field-scale SCF information. Studies have also shown that the timing of available forecasts can negatively affect smallholder farmers' production activities if not issued in line with key farming timelines for planting, weeding, etc.³³⁻³⁵ In other words, scientific SCFs should be delivered on a very regular basis and in time for farmers to be able to make informed decisions on short (monthly) and seasonal timelines. Furthermore, social and economic barriers, resulting in a divide between consumers and producers of SCFs^{34,35}, are a hindrance to the uptake of SCFs. Insufficient institutional ability to successfully convey and utilise climate information has also been cited as a barrier to the uptake of SCFs.¹³

The use and benefits of SCF among smallholder farmers have been constrained by legitimacy, limited access, limited skills and understanding, and data scarcity.¹² The reasons for poor utilisation of SCFs by smallholder farmers include perceived low forecast accuracy, out of context forecasts, short forecast lead time, inflexible farm management and other non-climatic risks like markets changes. Table 2 summarises the challenges facing farmers in climate forecast use. According to Hansen and Mason¹², and illustrated in Table 2, the challenges can be grouped into three categories: information content, access and socio-economic challenges.

Interdisciplinary studies have been cited as an emerging intervention to improve the value of SCFs. This involves the exploration of agricultural

decision-making with the integration of social and climate sciences.²⁶ The incorporation of social science will assist with the inclusion of farmers' opinions (as well as IKS) to make the forecast more usable for smallholder farmers. Despite some studies to evaluate the possibility of integrating IKS with scientific forecasts, not much has been done to assess the extent to which IKS influences decisions. As such, IKS could offer an entry point into the assessment of how to integrate forecasts in farm management decisions.^{22,23} Arunrat et al.²¹ also suggested that the use of IKS should be regarded as the basis for climate communication processes to ensure the formulation of relevant decisions when uncertainty arises for smallholder farmers.

Conclusion

The majority of smallholder rainfed farmers in Africa make use of either scientific or IKS derived forecasts, and in some cases, both SCF and IKS. The distinction between the two is that IKS is provided locally by the farmers themselves through observation of their environment, whereas SCFs are provided externally and remotely and allude to prepared climate information. Both systems of climate forecast have advantages and limitations. Drawing from the literature, we find that, at the farm level, reaching the right decisions at the right time is rendered even more difficult in light of increasing frequency of extreme weather patterns. The threat of climate change makes accurate climate forecasting essential for African smallholder farmers. Nonetheless, a SCF is only useful to a particular recipient if it is sufficiently accurate, timely and relevant to the actions that the recipient can take to make the right decisions to improve agricultural production. The usability of forecasts strongly depends on the characteristics of users, inclusive of both temporal and spatial aspects.

Technological, social and interdisciplinary issues, communication, and scale are some key challenges which impact the utility and uptake of SCFs in rural smallholder farms. Integration of SCF and IKS is an opportunity that could be explored but requires further research. SCFs have attracted a lot of research attention in recent years, but most research has focused on improving forecasting skills, reliability, accessibility and accuracy. Indeed, these are key areas that require continuous improvement. Nevertheless, as SSCFs are improved, there is also a need to continuously test their usability and influence on decision-making. A good forecast is one that leads to informed decisions and improved agricultural production. There have been mixed results in the area of evaluating benefits of SCF in decision-making and farm production. In some instances, the outcomes have been positive, whereas, in other circumstances, the outcomes have been difficult to quantify. This review shows that there still are some challenges in using SCFs which stem from inadequate understanding around how and why smallholder farmers make decisions. Therefore, the value of and methods

Table 2: Challenges to climate forecast use by farmers

Categories of challenge	Challenges	Impact on farmers decisions	References
Content of the SCF products	Coarse spatial scale and lacks local information	Affects the relevance of the forecast to the farming decisions	Patt and Gwata ³⁶
	Lack of information about timing of rainfall		Klopper et al. ³⁷
	Lack of information about season onset or length		Klopper et al. ³⁷ , Archer ³⁸
	Not clear on temporal scale of the forecast		Klopper et al. ³⁷
	Forecast accuracy not sufficient		UNDP ³⁹
Access to SCF information/products	Inequitable access	Timing of farming operations like weeding, planting is affected	Archer ³⁸ , UNDP ³⁹ , Phillips et al. ⁴⁰
	Forecasts available too late		UNDP ³⁹
	Neglected communication of favourable forecasts, bias toward adverse conditions		Phillips et al. ⁴⁰
Smallholder farmers' lack of resources	Limited access to draft power	Influences the response to SCF	Phillips et al. ⁴⁰
	Limited access to seed of desired cultivars		Klopper et al. ³⁷
	Limited access to credit		Klopper et al. ³⁷
	Limited access to fertile soils		Klopper et al. ³⁷

Adapted from Hansen and Mason¹²

to improve these SCFs with respect to smallholder farmers need to be further evaluated.

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Authors' contributions

B.C. was responsible for the conception and design of the study; reviewing the literature; and writing the initial draft. A.M. was responsible for revising the article and providing final approval of the version to be published; student supervision; and oversight of the study. K.N. was responsible for writing and revising the manuscript; and student supervision. E.E.P. was responsible for writing and revising the manuscript.

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